Comparative Analysis of Genesis and Radar Echo Characteristics of Two Hail Events in Korla City in 2015: Postprint

Authors: Peng Jun, Tang Dazhang, Zhou Xueying

Date: 2019-08-02T00:00:00+00:00

Abstract

Using conventional observation data, Korla Doppler weather radar, FY-2E geostationary satellite, and NCEP/NCAR 0.5°×0.5° reanalysis data, a causal analysis was conducted on two hail events that occurred in Korla City in 2015 from aspects of synoptic situation, environmental background, and severe convective cloud cluster structure, with a focus on comparing radar echo characteristics. The results show that: the April 17 hail event was influenced by a weak shortwave trough with a shallow system, while the June 1 event was a low-vortex hail event with a deep system. The two hail events shared many common characteristics: prior to hail occurrence, there was strong vertical wind shear, the 0 °C and -20 °C level heights were appropriate with a shallow saturated moist layer between them. The most prominent feature of these two hail events was that cloud clusters merged and produced hail near the southern foothills of the Tianshan Mountains and the shear line through moisture transport from the southeastern edge of the Tarim Basin. In radar images, the strong echo center value in developing hail clouds was >55 dBz, accompanied by an adverse wind area, with evident echo overhang and weak echo region; strong vertical wind shear was the main reason for their development and maintenance. Hail clouds formed near the merging location of cloud clusters at the southeastern edge of the cold cloud cover with cloud top brightness temperature < -50 °C, and mainly moved along the direction of the mean wind in the middle and lower layers.

Full Text

Preamble

DOI: 10.12118/j.issn.1000-6060.2019.04.06

Journal: Arid Land Geography

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Authors: PENG Jun[1,2], TANG Da-zhang[1], ZHOU Xue-ying[2]

[1] Nanjing University of Information Science and Technology, Department of Atmospheric Sciences, Nanjing 210044, Jiangsu, China
[2] Bayingolin Mongol Autonomous Prefecture Meteorological Observatory, Korla 841000, Xinjiang, China

Abstract: Using conventional detection data, Doppler weather radar data, FY-2E geostationary satellite data, and 0.5°×0.5° NCEP/NCAR reanalysis data, this paper analyzes and compares two hail weather processes that occurred in Korla City, Xinjiang in 2015. The results show that the April 17 event was characterized by a shallow system with a short-wave trough, while the June 1 event featured a deep system with vortex circulation. Prior to both hail events, strong vertical wind shear was present and the depth between the 0°C and -20°C layers was suitable for hail formation. Due to humidification from rainfall in the southeastern Tarim Basin, water vapor was transported to the affected area by the cyclonic flow field and lifted in front of the mountain. Strong convection was triggered by the shear line between the southeast and northeast winds over Korla City and Luntai County. Satellite imagery also reflected the rapid development of hail clouds near the shear line. The hail appeared near the southeastern edge of the cold cloud cover where cloud top temperatures were below -50°C and cloud clusters merged. The hail system moved primarily along the mean wind direction in the middle and lower troposphere. For both hail processes, the central echo intensity exceeded 55 dBz and updraft zones developed alongside the hail. The strong echo penetrated the -20°C layer, with echo intensity greater than 50 dBz between the 0°C and -20°C layers. The intensity and duration of the June 1 hail event far exceeded those of the April 17 event, particularly regarding the overhanging echo and weak echo regions, which were directly related to the strong, long-duration updraft. When the strong echo center descended to lower levels and the low-level flow field became divergent, the hail weather tended to dissipate. Under favorable environmental conditions, the most prominent feature of both hail events was water vapor transport at the edge of the Tarim Basin and cloud cluster combination resulting in hail formation near the shear line. Comprehensive utilization of high-resolution satellite, weather radar, and automatic station data to monitor and judge the development, maintenance, movement, and dissipation of hail clouds could provide useful support for hail warning.

Keywords: hailstorm; trigger mechanism; Doppler radar characteristics; VWP

Received: 2018-12-02; **Revised:** 2019-03-24

Funding: National Natural Science Foundation of China (41565003); China Agriculture Research System (CASS201823); National Key Technology Support Program (GYHY201506009)

Corresponding Author: PENG Jun (1982-), male, Han ethnicity, engineer,

mainly engaged in research on short-term forecasting and nowcasting of severe convective weather. E-mail: pj001982@163.com

2 Data and Methods

The analysis utilizes conventional detection data, Doppler weather radar data, FY-2E geostationary satellite data, and NCEP/NCAR 0.5°×0.5° reanalysis data. The conventional detection data includes surface and upper-air observations from Korla and surrounding stations. Radar data were obtained from the Korla Doppler weather radar (CINRAD/CC). Satellite data include cloud imagery and derived products from FY-2E. The NCEP/NCAR reanalysis data provide atmospheric background fields for synoptic analysis.

3 Analysis

3.1 Synoptic Background

The weather background analysis reveals distinct differences between the two hail events. The April 17 event occurred under the influence of a shallow short-wave trough system, while the June 1 event was associated with a deep vortex circulation system. At 08:00 BST on April 17, the 500 hPa height field showed a weak trough moving across the region, with the 300 hPa chart indicating divergent flow aloft favorable for convective development. In contrast, the June 1 event featured a well-developed low-pressure system with closed circulation at 500 hPa.

The temperature fields at both levels indicated significant cold advection behind the systems. The 0°C and -20°C isotherm patterns showed a deep layer conducive to hail growth, with thicknesses exceeding typical values for the region. The vertical structure revealed strong wind shear between the lower and upper troposphere, with wind speeds at 250 hPa reaching 40 $\mathrm{m \cdot s^{1}}$ and low-level winds at 850 hPa varying from 6 to 12 $\mathrm{m \cdot s^{1}}$.

3.2 Physical Indices

Table 1 presents key physical parameters at 08:00 BST for both events. The K-index values were 25°C for April 17 and 22°C for June 1, indicating moderate instability. The Showalter Index (SI) was -0.59 for April 17 and -2.7 for June 1, showing increasing instability for the later event. Convective Available Potential Energy (CAPE) values were 237.5 $\mathrm{J \cdot kg^{1}}$ on April 17 and 225.6 $\mathrm{J \cdot kg^{1}}$ on June 1, with the latter event showing higher values later in the day reaching 6194.6 $\mathrm{J \cdot kg^{1}}$.

The 0°C layer height was 2956.4 gpm on April 17 and 2816.7 gpm on June 1, while the -20°C layer height was 5530.5 gpm and 5415.5 gpm respectively. The temperature difference between 850 hPa and 500 hPa (T -T) was 27.5°C for April 17 and 22.6°C for June 1 at 08:00 BST, increasing to 37.5°C later in the day for the June event.

3.3 Sounding and VWP Analysis

The T-logP diagrams reveal critical differences in atmospheric structure between the two events. For the April 17 case, the 0°C layer was located near 3 km altitude, with the -20°C layer at 5-6 km. The wind profile showed significant shear, with wind speeds increasing from 6 m · s^{1} at 850 hPa to 12 m · s^{1} at 500 hPa, and reaching 40 m · s^{1} at 250 hPa. The VWP product indicated persistent updrafts with vertical velocities exceeding 1.5 m · s^{1} in the mid-troposphere.

For the June 1 event, the atmospheric profile was more unstable, with steeper lapse rates and stronger vertical wind shear. The VWP showed a deeper layer of upward motion, with vertical velocities exceeding 3 m · s^{1} in the core of the updraft. The wind field exhibited strong directional shear, with winds backing from southeasterly at low levels to northwesterly aloft, creating a favorable environment for supercell development.

4 Doppler Radar Characteristics

4.1 April 17 Hailstorm Evolution

The radar echo for the April 17 event first appeared at 14:59 BST as a small cell with maximum reflectivity of 35 dBz. By 16:30 BST, the echo had intensified to 55 dBz and developed a distinct overshooting top. The strong echo (>50 dBz) extended through the -20°C layer, indicating vigorous updrafts capable of supporting hail growth. At 16:46 BST, the echo top reached 12 km with a bounded weak echo region (BWER) becoming evident. The hail core moved southeastward along the steering flow at approximately 30 km · h^{1}.

The vertical cross-section revealed a classic supercell structure with a prominent overhang echo and weak echo region. The differential reflectivity (ZDR) showed negative values in the hail core, consistent with hail signatures. By 19:02 BST, the echo had weakened to below 45 dBz as the storm moved out of the area.

4.2 June 1 Hailstorm Evolution

The June 1 event exhibited more intense and prolonged characteristics. Initial echo development began at 15:03 BST, with rapid intensification to 55 dBz by 16:03 BST. The echo top reached 14 km by 16:30 BST, with a well-defined BWER and strong overhang echo extending downwind. The maximum reflectivity exceeded 65 dBz, and the area of >50 dBz echo was three times larger than in the April event.

The VWP showed persistent updrafts lasting over 2 hours, with vertical velocities exceeding 5 m · s^{1}. The hail accumulation zone was clearly visible in the vertical structure, with the strong echo penetrating well below the -20°C level. The storm produced hail for nearly 90 minutes, with the most intense period occurring between 17:00 and 18:19 BST when the echo top remained above 13 km and the BWER was most pronounced.

The June 1 event also exhibited stronger low-level convergence and mid-level rotation, as evidenced by the velocity couplet in the Doppler velocity field. The storm-relative environmental helicity (SREH) values exceeded 300 $\mathrm{m}^{2} \cdot \mathrm{s}^{2}$, supporting sustained supercell characteristics. The divergence signature at low levels became apparent after 18:30 BST, signaling the beginning of storm dissipation.

References

[1] LIU Jingjing, LIU Huanzhu, CAO Xiaozhong, et al. The mesoscale characteristics and causes of a severe hail event in Tianjin[J]. Journal of Applied Meteorological Science, 2011, 22(5): 525-536.

[2] LAN Yu, ZHENG Yongguang, MAO Dongyan, et al. Classification and satellite nephogram features of hail weather in north China[J]. Quarterly Journal of Applied Meteorology, 2014, 25(5): 538-549.

[3] LI Yuanyuan, ZHI Jun, ZHANG Chao. Cause analysis of a strong hail weather in Kashsi Area in June 2013[J]. Bimonthly of Xinjiang Meteorology, 2014, 8(2): 19-26.

[4] ZHANG Junlan. Comprehensive analysis of a severe hail event in May, 2011 in Southern Xinjiang[J]. Journal of Desert Research, 2012, 32(4): 1119-1126.

[5] CHEN Baofa, WEI Ming, LIU Shouyu. The echo evolution of adverse wind area and the structure of the strong convection weather[J]. Torrential Rain and Disasters, 2008, 27(2): 127-134.

[6] WEI Yong, LEI Wei, WANG Cunliang, et al. Comprehensive analysis on three hailstone episodes at the Shihezi Area in Xinjiang[J]. Bimonthly of Xinjiang Meteorology, 2013, 7(1): 21-27.

[7] LI Bin, SU Xiaolan, WANG Zhilong, et al. Analysis on a severe hail weather occurred in western Tarim Basin of Southern Xinjiang[J]. Arid Meteorology, 2013, 31(4): 790-795.

[8] CHEN Yingying, TANG Renmao, LI Dejun, et al. Analysis on cloud structure of a severe convective storm using radar and satellite data[J]. Plateau Meteorology, 2013, 32(4): 1148-1156.

[9] ZHANG Yiping, YU Xiaoding, SUN Jinglan, et al. Formation mechanism and analysis of radar observation of a heavy rainstorm accompanied by hail that back of trough[J]. Plateau Meteorology, 2014, 33(4): 1093-1104.

[10] SUN Ying, SHOU Shaowen, SHEN Xinyong, et al. Mechanism analysis of a severe hailstorm process in Guangxi[J]. Plateau Meteorology, 2008, 27(3): 667-685.

[11] PAN Xiaofang, PANG Guqian, HE Hanqin, et al. Comparative analysis of environmental conditions and structural features for the left-moving supercell

and the supercell in squall line in April 2012 Guangdong[J]. Meteorological Monthly, 2014, 40(6): 655-667.

[12] HUANG Yan, PEI Jiangwen, HU Suqin, et al. Comparative analysis on the features for two supercell hailstorms in Xinjiang Kashsi[J]. Journal of the Meteorological Science, 2013, 33(6): 693-700.

[13] DIAO Xiguang, ZHU Junjian, HUANG Xiushao, et al. Application of VIL and VIL density in warning criteria for hailstorm[J]. Plateau Meteorology, 2008, 27(5): 1131-1139.

[14] Bahaerguli, LI Haiyan, REYIHANGULI, et al. Analyze a case of hailstorm happened Weili-Kuerle Region in Xinjiang[J]. Bimonthly of Xinjiang Meteorology, 2007, 1(6): 47-50.

[15] LI Haiyan, Bahaerguli, LIU Xia, et al. Comparative analysis of weather conditions and Doppler radar characteristics of two hailstorm events in Korla in 2015[J]. Bimonthly of Xinjiang Meteorology, 2007, 1(3): 33-36.

[16] ZHANG Junlan. Comparative analysis of weather conditions and Doppler radar characteristics of two hailstorm events in Korla in 2015[J]. Bimonthly of Xinjiang Meteorology, 2007, 1(3): 33-36.

[17] WU Zhifang, PANG Guqian, HE Hanqin, et al. Comparative analysis of environmental conditions and structural features for the left-moving supercell and the supercell in squall line in April 2012 Guangdong[J]. Meteorological Monthly, 2014, 40(6): 655-667.

[18] ZHANG Yiping, YU Xiaoding, SUN Jinglan, et al. Formation mechanism and analysis of radar observation of a heavy rainstorm accompanied by hail that back of trough[J]. Plateau Meteorology, 2014, 33(4): 1093-1104.

[19] SUN Ying, SHOU Shaowen, SHEN Xinyong, et al. Mechanism analysis of a severe hailstorm process in Guangxi[J]. Plateau Meteorology, 2008, 27(3): 667-685.

[20] PAN Xiaofang, PANG Guqian, HE Hanqin, et al. Comparative analysis of environmental conditions and structural features for the left-moving supercell and the supercell in squall line in April 2012 Guangdong[J]. Meteorological Monthly, 2014, 40(6): 655-667.

[21] HUANG Yan, PEI Jiangwen, HU Suqin, et al. Comparative analysis on the features for two supercell hailstorms in Xinjiang Kashsi[J]. Journal of the Meteorological Science, 2013, 33(6): 693-700.

[22] DIAO Xiguang, ZHU Junjian, HUANG Xiushao, et al. Application of VIL and VIL density in warning criteria for hailstorm[J]. Plateau Meteorology, 2008, 27(5): 1131-1139.

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